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Plutonium Air Inhalation Dose (PAID): A Code for Calculating Organ Doses Due to the Inhalation and Ingestion of Radioactive Aerosols

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by

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INTRODUCTION

This technical note describes a computer code, PAID, developed to determine time dependent dose rates and doses from inhaled or ingested radionuclides. The main purpose of this code is to determine the dose rates and doses caused by the intake of transuranic nuclides and their decay products.

The two primary modes leading to internal radiation exposure are the inhalation and ingestion of radioactive materials. The estimation of organ burden and exposure,* as well as of the resulting dose rates and doses, due to uptake by these pathways is relatively complicated and requires the adoption of mathematical models which depend on many parameters. A computer code which implements the lung model described by the ICRP Task Group on Lung Dynamics is presented below. This model has been augmented to also include the dose due to the transfer of radioactivity to other organs from ingested materials.

A. Inhalation

Industrial hygienists have recognized for many years that the inhalation of an aerosol carrying radioactive nuclides was a potential mechanism for damage to the respiratory tract as well as a possible pathway for the translocation of inhaled radioactive material to other reference organs. The complexity of the biological phenomena which govern transmission and elimination of such material complicates the consideration of potential health effects due to inhalation of radioactive materials. Even a first order analysis of the process must consider the factors enumerated below:

*The time integral of the burden has been referred to as the exposure by the ICRP.

(1) The fractional deposition of inhaled material in the respiratory tract depends on properties of the aerosol - size and mass distribution, chemical form and charge - as well as on the breathing rate and such physiological characteristics of the lung as its surface properties and configuration.

(2) The duration and extent of the exposure depends on the biological and physical mechanisms which transport the deposited material and its decay product within the body. These include the various clearance paths, the nuclide half-lives, the chemical form, the solubility, and the degree of retention in each reference organ of interest.

(3) The dose depends on the time integrals of the activity of both parent and daughter in the organ, the organ mass, the emitted energy of each nuclide, and the fraction of that energy absorbed by the organ tissues. For alpha emitters, this absorbed fraction is assumed to be unity. At present, the organ mass, breathing rate, and clearance times in the PAID code correspond to those of a 30-year old working male (1). Specific parameters are given in the text below. The dose is calculated in rads - neither quality factors nor other dose modifying factors are included in this program.

B. Ingestion

The ingestion of radioactive material represents another pathway by which radioactivity may be transferred to blood and, subsequently, to other organs. While description of this pathway is simpler than for inhalation, due to the direct deposition of the ingested material into the gastrointestinal tract, treatment of the balance of the

biological - physical processes involved suffers from the same uncertainties in biological parameters as were discussed for the inhalation model. The dose to the gastrointestinal tract itself is not calculated by this program, nor is the normally negligible time delay associated with transfer of the material through the stomach and small intestine considered.

In the ingestion model, the critical transfer mechanism is the absorption of radioactive material into the systemic blood from the small intestine. Values for the fraction, f_1, of ingested radioactivity transferred to blood have been studied in animals and, to a very limited extent, in man but are still subject to large uncertainties which strongly affect projected doses to the reference internal organs, i.e., bone, liver, etc.

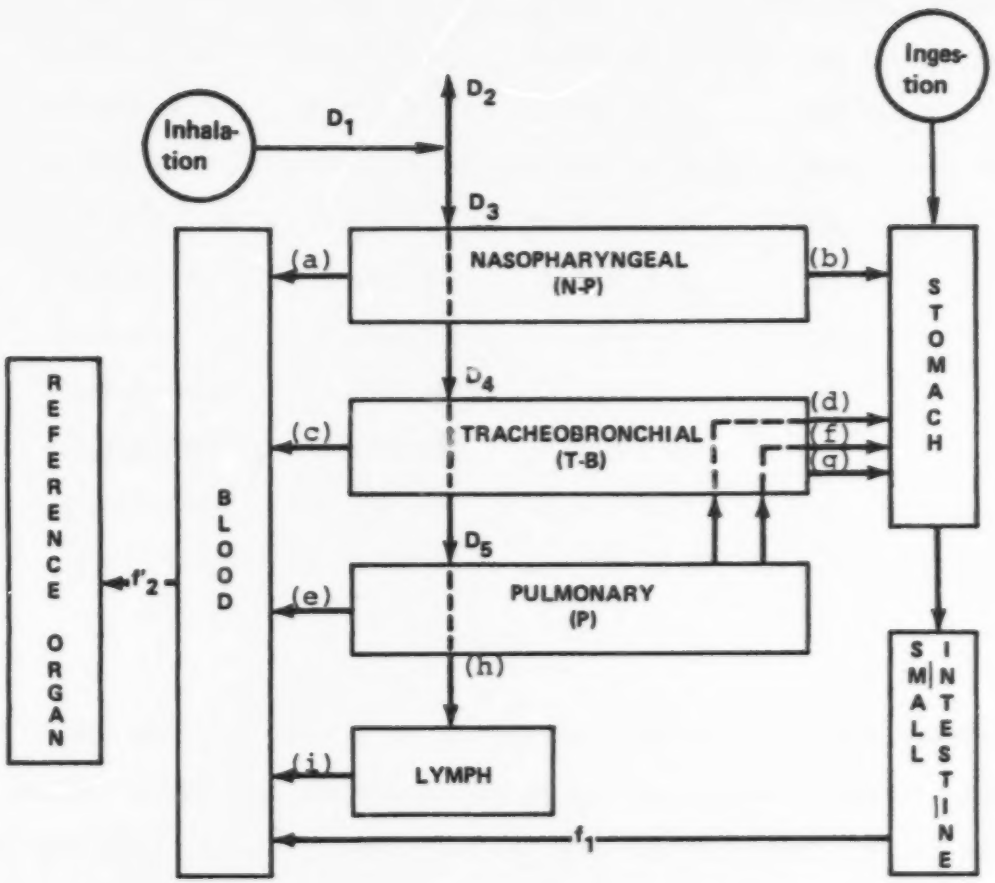
C. The Physical Model

Reasonable estimates of internal radiation doses due to inhalation and ingestion require that a consistent model for both the respiratory and gastrointestinal tracts be employed. While a large amount of theoretical and experimental work on such models has been done, the most widely accepted models have been those developed by members of the respective International Commission on Radiological Protection (ICRP) working groups.

The ICRP Task Group on Lung Dynamics (TGLD) has proposed a model for the respiratory tract which has been well documented (2). Parameters suggested for use in the model have been extensively reviewed and, to some extent, improved in later ICRP publications (3). Details of this model are given by Morrow and the revised parameters

have been collected by the ICRP in reference (3). Therefore, only a brief outline of the model is presented here. The ICRP TGLD proposed model comprises three major compartments: the nasopharyngeal, the tracheobronchial and the pulmonary, as shown in Figure I.
Each of these major compartments is divided into subcompartments, corresponding to various transfer mechanisms, which are treated as essentially independent processes. In addition, the associated lymph nodes are appended to the pulmonary compartment in one of the transfer chains. Direct deposition through inhalation is only to the three major compartments with the fractional deposition in each a function of the aerosol properties. Subsequent transfer and/or clearance is governed by the parameters specified for each subcompartment, as shown in Table I, taken from reference (3). Pathways are indicated in Figure I.

FIGURE 1



D_1 is the total aerosol inhaled; D_2 is the aerosol in the exhaled air; D_3, D_4, and D_5 are the amounts deposited in the nasopharyngeal, tracheobronchial, and pulmonary lung respectively. The letters (a) through (i) indicate the process which translocates material from one compartment to another. Values for these parameters are listed in Table I.

Table I

Biological Half-lives in Days and Transfer

Fractions for Use with TGLD Clearance Model

Region	Pathway	Compound Class (D)	(W)	(Y)
N-P	(a)	0.01 d/0.5	0.01 d/0.1	0.01 d/0.01
	(b)	0.01 d/0.5	0.4 d/0.9	0.4 d/0.99
T-B	(c)	0.01 d/0.95	0.01 d/0.5	0.01 d/0.01
	(d)	0.2 d/0.05	0.2 d/0.5	0.2 d/0.99
P	(e)	0.5 d/0.8	50 d/0.15	500 d/0.05
	(f)	---	1 d/0.4	1 d/0.4
	(g)	---	50 d/0.4	500 d/0.4
	(h)	0.5 d/0.2	*50 d/0.05	500 d/0.15
L	(i)	0.5 d/1.0	50 d/1.0	1000 d/0.9

*A value of 50.01 is substituted in the code.

In connection with this table, it should be noted that the code described in Appendices I and II is not suitable for decay chains in which the parent and daughter are in different classes. Its use is also restricted to the analysis of compartments not having identical biological half-lives. However, the decay of the parent into a radioactive daughter is explicitly treated for the case in which both are Class Y or Class W compounds. While not contained in the present code, the solutions for Class D compounds are contained within the general equations derived below.

An ICRP gastrointestinal tract model has been documented (4). The model comprises a four compartment tract consisting of the stomach, small intestine and lower and upper large intestine. The times involved in the passage of material through the stomach and small intestine (the only compartment from which transfer into the blood occurs) are negligible compared to the half-lives associated with most class Y compounds and are neglected when considering doses due to ingestion.

Although both these models are described exhaustively in words, neither of the ICRP groups has given mathematical descriptions for the various processes involved. This lack has led to some confusion in attempting to calculate doses and effects using the models. For the present treatment, several of the previous analyses, (5,6,7), have been reviewed and discrepancies or omissions in their equations compared with the "official" verbal descriptions of the models. While some ambiguities may remain, the present treatment has attempted to reconcile differences between the ICRP descriptions and these earlier codes. Several features, not common to all previous codes, which have been incorporated into PAID include: (1) explicit calculation of the dose rates and doses due to both parent and daughter products, (2) inclusion of the dose to the tracheobronchial region due to the clearance of material deposited in the pulmonary region, (3) calculation of the dose from material permanently retained in the lymph nodes, (4) separate calculation (and printout) of the percentage of the total dose to a reference organ due to absorption from the gastrointestinal tract for both parent and daughter. This latter

feature allows various values of f_1 to be substituted without repeating the whole calculation.

D. The Mathematical Model

The PAID code used by the Environmental Protection Agency (EPA) corresponds to descriptions of the physiological processes as contemplated by the originating ICRP working group. In addition, an attempt has been made to keep the resulting mathematical relationships as simple and understandable as possible. To this end, the respiratory and gastrointestinal tract models have been coupled as outlined below:

The ICRP TGLD model implicitly assumes that the physiological processes associated with each subcompartment operate independently. The simplest mathematical treatment of the model is to consider a chain consisting of up to three components for both parent and daughter. The first component in each chain represents a lung subcompartment, the second either the reference organ or the lymph nodes, and the last the reference organ for the lung-lymph node pathway. For the ingestion pathway only one component - representing the reference organ - is used since the dose to the gastrointestinal tract is not calculated. A general differential equation governing the behavior of each series - connected component in a chain of arbitrary length may be written as:

(1)

$$\dot{q}^n(t) = S^n(t) - \lambda^n q^n(t)$$

where $q^n(t)$ = the organ or subcompartment burden (curies) for the nth subcompartment

$S^n(t)$ = the source term for the nth compartment (curies/yr)

λ^n = the total, or effective, decay constant for the radionuclide in the nth compartment (yr^{-1})

The source term will vary, depending on the position of the compartment in the chain and whether the parent or daughter is under consideration. Direct deposition within the lung is through inhalation of the parent and is into the major compartments; nasopharyngeal, tracheobronchial and pulmonary. These major compartments are further divided into subcompartments and their associated pathways; (a) through (i) listed in Table I.

Consider first the equations for the organ burden due to the parent, S_p. The source term in the first compartment (subcompartment) of the lung will be:

$$S_p^1(t) = I_c D_k f_\ell$$

where D_k is the deposition fraction for the major compartment as shown in (2); f_ℓ is the fraction of D_k translocated through pathway ℓ, Table I and I_c is the rate (curies/year) of constant chronic intake based on the breathing rate given in Table II. Thus, I_c = (Breathing Rate) x (Air Concentration). Mathematically, any acute intake is presumed to be present at time zero, i.e.,

$$q(t = 0) = I_A D_k f_\ell \qquad (2)$$

where the subscript A denotes acute and q (t=0) is inserted as a boundary condition.

Table II

Breathing Rate - Male Adult ICRP Report #23 (ICRP 1975)

	Minute Volume (liters/minute)	Duration (hours/day)
Light Activity	20.0	16
Resting	7.5	8

Average Daily Intake = 2.3×10^4 liters.

For ingestion, the only component is the reference organ and the source here is:

$$S_p^1 (t) = I_c$$

where, again, I is the annual intake in curies for constant, continuous ingestion. Any acute intake is, again, treated as a boundary condition.

For succeeding components in the chain, the only source for parent radionuclides is material transmitted from the preceeding compartment. All organs (subcompartments) inferior in position to the first are presumed to have no initial radionuclide content, q(o) = 0. Therefore, for all subsequent organs

(3)

$$S_p^n (t) = f_p^n \, {}^b\lambda_p \, q^{n-1}$$

where n-1 refers to the preceeding member of the chain and $^{b}\lambda_p$ is the biological decay constant of the parent. It is obvious, from the last equation, that each equation in the chain is coupled to all preceeding equations through the source term.

Coupled equations of this type are most readily solved by using Laplace transforms.(8) Application of a Laplace transform to Equation 1 yields, using s as the transformed variable,

$$sq^n(s) - q_o^n = S^n(s) - \lambda^n q^n(s) \tag{4}$$

where, to simplify the notation $\mathcal{L}\{q(t)\}$ is written as q(s). Then,

$$q^n(s) = \frac{S^n(s)}{s(s + \lambda^n)} + \frac{q_o^n}{(s + \lambda^n)}$$

and q_o^n is the initial burden, due to acute intake. The initial organ burden for all organs inferior to the first is set equal to zero. Furthermore, the source terms for the first organ (or subcompartment) are constant and their transforms will be:

$$S_p^1(s) = \frac{I_c D_k f_\ell^1}{s} \tag{5}$$

for inhalation or

$$S_p^1(s) = \frac{I_c}{s} \tag{6}$$

for ingestion. Again I_c represents a constant, continuous intake (Ci/yr). The general equation then becomes, in transform space,

$$q_p^1(s) = \frac{I_c D_k f_p^1}{s(s + \lambda_p^1)} + \frac{q_o^1}{(s + \lambda_p^1)} \tag{7}$$

for the first component of the chain, where q_o^1, if present, is given by equation 2. Using the transformed Equation 7 as the source in Equation 3, the equation for the second member of the chain is seen to be

$$q_p^2(s) = \frac{b\lambda_p^1 f_p^2}{(s + \lambda_p^2)} \left[\frac{I_c D_k f_p^1}{s(s + \lambda_p^1)} + \frac{q_o^1}{(s + \lambda_p^1)} \right] \tag{8}$$

from which it is obvious that the equation for each succeeding component differs only by an additional factor $(s + \lambda)$ and, of course, by modification of the coefficient by the terms f_p^n and λ^{n-1}, the translocation fraction to the next organ and the biological decay constant of the previous, respectively. The general equation for the nth organ or subcompartment may then be written as:

$$q_p^n(s) = \prod_{i=1}^{n} f_p^i \, b \, \lambda_p^{i-1} \left\{ \frac{I_C D_k}{s\left[\prod_{i=1}^{n}(s + \lambda_p^i)\right]} + \frac{q_o^1}{\left[\prod_{i=1}^{n}(s + \lambda_p^i)\right]} \right\} \tag{9}$$

where λ° is defined as 1 and the first term corresponds to the continuous intake case and the last to the acute intake case.

The governing equations for the daughter product are similar to those for the parent with appropriate changes in the source terms. One question, which has not been addressed by the ICRP, is whether the decay product remains in the parental chain, or whether the total decay product in a given compartment should be reapportioned according to its transfer fractions. In the PAID code, the former assumption has been made, i.e., the daughter formed by decay of the parent in a given clearance pathway is assumed to continue to clear through that pathway although governed by its own physical parameters. For the first component in the chain, the only source is decay of the parent and equation (1) becomes

$$\dot{q}_D^n(t) = S_D^n(t) - \lambda_D^n q_D^n(t) \tag{10}$$

where the symbols are as for the parent with D denoting the daughter product. Taking the transform of this, noting that $S_D^1 = {}^r\lambda_D q_p^1(t)$ and substituting $q_p^1(s)$ from equation 7,

$$q_D^1(s) = {}^r\lambda_D \left[\frac{I_c D_k f_p^1}{s(s + \lambda_p^1)(s + \lambda_D^1)} + \frac{I_A D_k f_p^1}{(s + \lambda_p^1)(s + \lambda_D^1)} \right] \tag{11}$$

where ${}^r\lambda$ is the physical decay constant.

For the second, and succeeding components, the source term comprises two parts; that describing the decay of the parent in the

same compartment and that describing translocation of the daughter from the preceeding compartment, thus

$$q_D^2(t) = {}^{r}\lambda_D q_p^2(t) + {}^{b}\lambda_D^1 f_D^2 q_D^1(t) \tag{12}$$

and

$$q_D^2(s)\left[s + \lambda_D^2\right] = {}^{r}\lambda_D q_p^2(s) + {}^{b}\lambda_D^1 f_D^2 q_D^1(s) \tag{13}$$

Substituting the $q_p^2(s)$ and the $q_D^1(s)$ derived above, the second compartment daughter burden becomes

$$q_D^2(s) = {}^{r}\lambda_D \left[\frac{{}^{b}\lambda_p^1 f_p^2 I_c D_k f_p^1}{s(s+\lambda_p^1)(s+\lambda_p^2)(s+\lambda_D^2)} + \frac{{}^{b}\lambda_p^1 f_p^2 I_A D_k f_p^2}{(s+\lambda_p^1)(s+\lambda_p^2)(s+\lambda_D^2)}\right] + {}^{b}\lambda_D^1 f_D^2 \left[\frac{{}^{r}\lambda_D I_c D_k f_p^1}{s(s+\lambda_p^1)(s+\lambda_D^1)(s+\lambda_D^2)} + \frac{{}^{r}\lambda_D I_A D_k f_p^1}{(s+\lambda_p^1)(s+\lambda_D^1)(s+\lambda_D^2)}\right] \tag{14}$$

For the third compartment, the governing equation is the same but the source term becomes

$$S_D^3(t) = {}^{r}\lambda_D q_p^3(t) + {}^{b}\lambda_D^2 f_D^3 q_D^2(t) \tag{15}$$

from whence, again using the $q_p^3(s)$ and $q_D^2(s)$ obtained previously

$$q_D^3(s) = \frac{\alpha}{s(s+\lambda_p^1)(s+\lambda_p^2)(s+\lambda_p^3)(s+\lambda_D^3)} + \frac{\beta}{(s+\lambda_p^1)(s+\lambda_p^2)(s+\lambda_p^3)(s+\lambda_D^3)}$$

$$+ \frac{b_{\lambda_D^2} f_D^3 A}{s(s+\lambda_p^1)(s+\lambda_p^2)(s+\lambda_D^2)(s+\lambda_D^3)} + \frac{b_{\lambda_D^2} f_D^3 B}{(s+\lambda_p^1)(s+\lambda_p^2)(s+\lambda_D^2)(s+\lambda_D^3)} \qquad (16)$$

$$+ \frac{b_{\lambda_D^2} f_D^3 C}{s(s+\lambda_p^1)(s+\lambda_D^1)(s+\lambda_D^2)(s+\lambda_D^3)} + \frac{b_{\lambda_D^2} f_D^3 D}{(s+\lambda_p^1)(s+\lambda_D^1)(s+\lambda_D^2)(s+\lambda_D^3)}$$

where α, β, A, B, C, and D are given in Appendix I.

From both the parent and daughter derivations it is apparent that, although these equations may readily be extended to describe additional compartments and/or decay products, the resulting equations rapidly become quite prolix. As presently constituted, the PAID code comprises the first three compartments for both parent and daughter since these are sufficient to handle the problem under consideration.

However, the transformed differential equations are all similar, regardless of the number of compartments involved, i.e., the time (s) dependent terms are of the form

$$\frac{1}{(s-k_1)(s-k_2)\ldots(s-k_m)} \tag{17}$$

where k_1, k_2,...k_m are constants which may be positive, negative or zero. When k_1 is zero, the terms assume the form

$$\frac{1}{s(s-k_2)\ldots(s-k_m)} \tag{18}$$

It is easily noted that these terms differ only by the factor s in the denominator of the first. A well known theorem in transform theory states that division of the transformed equation by s corresponds to integration of the inverse transform between the limits 0 and t (8). Therefore, the solution to the continuous time intake case is the integral of the acute intake case.

The time integral of the organ burden, q(t), has been defined as the "exposure," Q (T), by the ICRP (9). Thus,

$$Q(T) = \int_o^t q(t)dt \tag{19}$$

The general equation for the exposure, in transform space, to any organ requires another integration over t. Again, this is obtained by dividing both terms of Equation q by s, corresponding to this integration. Thus quadratic, or higher terms,

$$\frac{1}{(s-k_1)^r(s-k_2)\ldots(s-k_m)} \tag{20}$$

where k_1 may be zero, are obtained.

Inverse transforms for equations of this form are readily found using an extension of the Heaviside partial fraction expansion and several well-known theorems from transform theory presented in reference (8). For the burden, q(t), equations, which do not involve

quadratic or higher order terms, applying the expansion to equations of the form (17) yields a general solution:

$$\mathcal{L}^{-1}\left[\frac{1}{g(s)}\right] = \sum_{m=1}^{M} \frac{e^{k_m t}}{g(k_m)} \qquad (21)$$

for both the acute case, corresponding to the equation (17) and the chronic case, equation (18). Solutions to equation (18), as mentioned, are also general solutions for the exposure, Q(T), for the case of acute intake.

Inverse transforms for equations containing repeated linear factors, while somewhat more tedious to calculate, are still straightforward (8). The general solution for terms having the form of equation (20) for the exposure, may be found by noting that (20) may be rewritten as:

$$\frac{\phi(s)}{(s - k_1)^r} \qquad (22)$$

where the inverse transform corresponding to the rth power term is:

$$F(t) = \sum_{r=0}^{n} \frac{\phi^{n-r}}{(n-r)!r!} t^r \exp(k_1 t) \qquad (23)$$

These solutions may, perhaps, be more readily verified by conventional integration of the burden equation.

One advantage of Laplace transforms is that an unlimited number of subcompartments, in series, may easily be treated, in a computer program loop, by addition of the appropriate term to the solution of the previous subcompartment. In addition, inverse transforms for the equations for Class D and Class W compounds, which contain terms in the denominator of the form $(s - k)^r$ are also found using the formulae in equation (23). Thus, it is possible, if the required parameters are known, to solve for transfer from the lung to a first reference organ (i.e. liver, bone, etc.) followed by subsequent translocation to another reference organ. Since the biological half-lives currently utilized with ICRP models are the net result of such processes as apposition and resorption, this feature is not used in the current version of the PAID code. However, use of this feature would provide a means of testing more general models of intercompartmental transfer than those proposed by the ICRP and, for this reason, may be of interest to investigators studying a range of metabolic problems.

For the lung, the dose is defined here as the average dose to a pulmonary compartment of 570 grams which is the mass of the pulmonary lung, including capillary blood, ICRP #23 (1). This dose may be used to estimate the risk of lung cancer. The dose rate, $\dot{D}$, and dose, D, are defined in terms of the organ burden, q, and exposure, Q, in uCi and uCi days, respectively:

$$\dot{D}(t) = 51.2 \frac{\varepsilon}{m} q(t) \text{ rad per day}$$

and

$$D(t) = 51.2 \frac{\varepsilon}{m} Q(t) \text{ rad}$$

where

ε = the absorbed energy (MeV) per disintergration for a particular isotope and organ pair.

m = the mass of the organ (grams)

Finally, health effects may be estimated by multiplying the dose to each organ by the number of effects expected per unit dose.

E. Computer Program

As previously stated, only the first three compartments for parent and daughter radionuclides, both of the same class, are presently contained in the PAID code. The complete solutions for these cases, obtained by applying formulae 21 and 23 to the transformed equations derived above, are presented in Appendix I. Appendix III is a listing of the code for Class Y compounds and Appendix II contains the input/output for a sample problem. The listing for Class W would be identical but for substituting the appropriate parameters from Table I.

To simplify the coding as much as possible, the procedure followed is to obtain the solution for each subcompartment in a chain. When the solutions for all chains are found, the subcompartments are then summed over to obtain total dose rates and doses for each major compartment or reference organ.

For ingestion, where the delay in the stomach and small intestine is neglected there is only one compartment, the reference organ.

Finally, two additional modifiers for the equations must be considered. First, for material which is transferred through the gastrointestinal tract, the additional fraction f_1 (transfer from small intestine to blood) must be used as a multiplier for organs inferior to the small intestine. Second, for material transferred through the systemic blood, the fraction f_2' (the fraction from blood to reference organ) must be incorporated into the product of the transmission fractions. These parameters are automatically inserted by the program.

Summary

The equations in Appendix I have been programmed for the IBM 360 computer in FORTRAN IV. Either the acute or constant continuous intake cases may be solved for both parent and daughter dose rate and dose. Built-in controls allow selection of the inhalation or ingestion case. The parameters for the ICRP model, shown in Table I, are built into the code. Only the reference organ parameters, i.e., fractional transmissions and biological half-lives, must be supplied as input. The assumption for the lymph nodes is that material not translocated to the reference organ remains in place and is lost only by radioactive decay. Explicit dose rates and doses to the tracheobronchial lung due to clearance of material from the pulmonary lung are printed out separately for both parent and daughter. The percentage of total dose due to transfer of material through the gastrointestinal tract is given for inhalation cases. General input instructions for the code are given in Appendix II.

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APPENDIX I

This Appendix gives the inverse transforms (time dependent solutions) of both parent and daughter for the first three compartments. The differential equations are derived in the text and the solutions found using the formula of equation (21). The solutions, as shown, are for the organ burden q(t), since these comprise the time dependent portion of the dose rate, equation (24). The exposures, Q(T), are not given since the integral of all terms in q(t) is either of the form

$$Q(T) = \frac{1}{k} \int_o^t dt = \frac{t}{k}$$

or

$$Q(T) = \frac{1}{k} \int_o^t \exp(-\lambda t)\ dt = \frac{1 - \exp(-\lambda t)}{k\lambda}$$

both of which are integrable by inspection. The organ burdens, q(t), for the parent compartments are:

(1)

$$q_P^1(t) = I_C D_k f_P^1 \left[\frac{1}{\lambda_P^1} + \frac{\exp(-\lambda_P^1 t)}{\lambda_P^1} \right] + I_A D_k f_P^1 \exp(-\lambda_P^1 t)$$

(2)

$$q_P^2(t) = b\lambda_P^1 f_P^2 f_P^1 I_C D_k \left[\frac{1}{\lambda_P^1 \lambda_P^2} + \frac{\exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_P^2)} + \frac{\exp(-\lambda_P^2 t)}{-\lambda_P^2(-\lambda_P^2+\lambda_P^1)} \right] +$$

$$b\lambda_P^1 f_P^2 f_P^1 I_A D_k \left[\frac{\exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_P^2)} + \frac{\exp(-\lambda_P^2 t)}{(-\lambda_P^2+\lambda_P^1)} \right]$$

(3)

$$q_P^3(t) = {}^{b}\lambda_P^{2b}\lambda_P^1 f_P^3 f_P^2 f_P^1 \left\{ \left[\frac{I_c D_k}{\lambda_P^1 \lambda_P^2 \lambda_P^3} + \frac{I_c D_k \exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_P^3)} + \right.\right.$$

$$\left.\left. \frac{I_c D_k \exp(-\lambda_P^2 t)}{-\lambda_P^2(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_P^3)} + \frac{I_c D_k \exp(-\lambda_P^3 t)}{-\lambda_P^3(-\lambda_P^3+\lambda_P^1)(-\lambda_P^3+\lambda_P^2)} \right] + \left[\frac{I_A D_k \exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_P^3)} + \right.\right.$$

$$\left.\left. \frac{I_A D_k \exp(-\lambda_P^2 t)}{(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_P^3)} + \frac{I_A D_k \exp(-\lambda_P^3 t)}{(-\lambda_P^3+\lambda_P^1+)(-\lambda_P^3+\lambda_P^2)} \right] \right\}$$

and for the daughter compartments:

(1)

$$q_D^1(t) = {}^{r}\lambda_D \left[\frac{I_c D_k f_P^1}{\lambda_P^1 \lambda_D^1} + \frac{I_c D_k f_P^1 \exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_D^1)} + \frac{I_c D_k f_P^1 \exp(-\lambda_D^1 t)}{-\lambda_D^1(-\lambda_D^1+\lambda_P^1)} + \right.$$

$$\left. \frac{I_A D_k f_P^1 \exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_D^1)} + \frac{I_A D_k f_P^1 \exp(-\lambda_D^1 t)}{(-\lambda_D^1+\lambda_P^1)} \right]$$

(2)

$$q_D^2(t) = A\left[\frac{1}{\lambda_P^1\lambda_P^2\lambda_D^2} + \frac{\exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_D^2)} + \frac{\exp(-\lambda_P^2 t)}{-\lambda_P^2(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_D^2)} + \frac{\exp(-\lambda_D^2 t)}{-\lambda_D^2(-\lambda_D^2+\lambda_P^1)(-\lambda_D^2+\lambda_P^2)}\right] + B\left[\frac{\exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_D^2)} + \frac{\exp(-\lambda_P^2 t)}{(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_P^2)} + \frac{\exp(-\lambda_D^2 t)}{(-\lambda_D^2+\lambda_P^1)(-\lambda_D^2+\lambda_P^2)}\right] + C\left[\frac{1}{\lambda_P^1\lambda_D^1\lambda_D^2} + \frac{\exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_D^1)(-\lambda_P^1+\lambda_D^2)} + \frac{\exp(-\lambda_D^1 t)}{-\lambda_D^1(-\lambda_D^1+\lambda_P^1)(-\lambda_D^1+\lambda_D^2)} + \frac{\exp(-\lambda_D^2 t)}{-\lambda_D^2(-\lambda_D^2+\lambda_P^1)(-\lambda_D^2+\lambda_D^1)}\right] + D\left[\frac{\exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_D^1)(-\lambda_P^1+\lambda_D^2)} + \frac{\exp(-\lambda_D^1 t)}{(-\lambda_D^1+\lambda_P^1)(-\lambda_D^1+\lambda_D^2)} + \frac{\exp(-\lambda_D^2 t)}{(-\lambda_D^2+\lambda_P^1)(-\lambda_D^2+\lambda_D^1)}\right]$$

(3)

$$q_D^3(t) = \alpha \left[\frac{1}{\lambda_P^1 \lambda_P^2 \lambda_P^3 \lambda_D^3} + \frac{\exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_P^3)(-\lambda_P^1+\lambda_D^3)} + \right.$$

$$\frac{\exp(-\lambda_P^2 t)}{-\lambda_P^2(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_P^3)(-\lambda_P^2+\lambda_D^3)} + \frac{\exp(-\lambda_P^3 t)}{-\lambda_P^3(-\lambda_P^3+\lambda_P^1)(-\lambda_P^3+\lambda_P^2)(-\lambda_P^3+\lambda_D^3)} +$$

$$\left. \frac{\exp(-\lambda_D^3 t)}{-\lambda_D^3(-\lambda_D^3+\lambda_P^1)(-\lambda_D^3+\lambda_P^2)(-\lambda_D^3+\lambda_P^3)} \right] + \beta \left[\frac{\exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_P^3)(-\lambda_P^1+\lambda_D^3)} \right.$$

$$+ \frac{\exp(-\lambda_P^2 t)}{(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_P^3)(-\lambda_P^2+\lambda_D^3)} + \frac{\exp(-\lambda_P^3 t)}{-\lambda_P^3(-\lambda_P^3+\lambda_P^1)(-\lambda_P^3+\lambda_P^2)(-\lambda_P^3+\lambda_D^3)}$$

$$\left. + \frac{\exp(-\lambda_D^3 t)}{(-\lambda_D^3+\lambda_P^1)(-\lambda_D^3+\lambda_P^2)(-\lambda_D^3+\lambda_P^3)} \right] + A \left[\frac{b\lambda_D^2 f_2^3}{\lambda_P^1 \lambda_P^2 \lambda_D^2 \lambda_D^3} + \right.$$

$$\frac{b\lambda_D^2 f_2^3 \exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_D^2)(-\lambda_P^1+\lambda_D^3)} + \frac{b\lambda_D^2 f_2^3 \exp(-\lambda_P^2 t)}{-\lambda_P^2(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_D^2)(-\lambda_P^2+\lambda_D^3)}$$

$$+ \frac{b\lambda_D^2 f_2^3 \exp(-\lambda_D^2 t)}{-\lambda_D^2(-\lambda_D^2+\lambda_P^1)(-\lambda_D^2+\lambda_P^2)(-\lambda_D^2+\lambda_D^3)} + \left. \frac{b\lambda_D^2 f_2^3 \exp(-\lambda_D^3 t)}{-\lambda_D^3(-\lambda_D^3+\lambda_P^1)(-\lambda_D^3+\lambda_P^2)(-\lambda_D^3+\lambda_D^2)} \right]$$

$$+ B \left[\frac{b\lambda_D^2 f_2^3 \exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_P^2)(-\lambda_P^1+\lambda_D^2)(-\lambda_P^1+\lambda_D^3)} + \frac{b\lambda_D^2 f_2^3 \exp(-\lambda_P^2 t)}{(-\lambda_P^2+\lambda_P^1)(-\lambda_P^2+\lambda_D^2)(-\lambda_P^2+\lambda_D^3)} \right.$$

$$\left. + \frac{b\lambda_D^2 f_2^3 \exp(-\lambda_D^2 t)}{(-\lambda_D^2+\lambda_P^1)(-\lambda_D^2+\lambda_P^2)(-\lambda_D^2+\lambda_D^3)} + \frac{b\lambda_D^2 f_2^3 \exp(-\lambda_D^3 t)}{(-\lambda_D^3+\lambda_P^1)(-\lambda_D^3+\lambda_P^2)(-\lambda_D^3+\lambda_D^2)} \right] +$$

$$C\left[\frac{b\lambda_D^2 f_2^3}{\lambda_P^1\lambda_D^1\lambda_D^2\lambda_D^3} + \frac{b\lambda_D^2 f_2^3 \exp(-\lambda_P^1 t)}{-\lambda_P^1(-\lambda_P^1+\lambda_D^1)(-\lambda_P^1+\lambda_D^2)(-\lambda_P^1+\lambda_D^3)}\right.$$

$$+ \frac{b\lambda_D^2 f_2^3 \exp(-\lambda_D^1 t)}{-\lambda_D^1(-\lambda_D^1+\lambda_P^1)(-\lambda_D^1+\lambda_D^2)(-\lambda_D^1+\lambda_D^3)} + \frac{b\lambda_D^2 f_2^3 \exp(-\lambda_D^2 t)}{-\lambda_D^2(-\lambda_D^2+\lambda_P^1)(-\lambda_D^2+\lambda_D^1)(-\lambda_D^2+\lambda_D^3)} +$$

$$\left.\frac{b\lambda_D^2 f_2^3 \exp(-\lambda_D^3 t)}{-\lambda_D^3(-\lambda_D^3+\lambda_P^1)(-\lambda_D^3+\lambda_D^1)(-\lambda_D^3+\lambda_D^2)}\right] + D\left[\frac{b\lambda_D^2 f_2^3 \exp(-\lambda_P^1 t)}{(-\lambda_P^1+\lambda_D^1)(-\lambda_P^1+\lambda_D^2)(-\lambda_P^1+\lambda_D^3)} +\right.$$

$$\frac{b\lambda_D^2 f_2^3 \exp(-\lambda_D^1 t)}{(-\lambda_D^1+\lambda_P^1)(-\lambda_D^1+\lambda_D^2)(-\lambda_D^1+\lambda_D^3)} + \frac{b\lambda_D^2 f_2^3 \exp(-\lambda_D^2 t)}{(-\lambda_D^2+\lambda_P^1)(-\lambda_D^2+\lambda_D^1)(-\lambda_D^2+\lambda_D^3)} +$$

$$\left.\frac{b\lambda_D^2 f_2^3 \exp(-\lambda_D^3 t)}{(-\lambda_D^3+\lambda_P^1)(-\lambda_D^3+\lambda_D^1)(-\lambda_D^3+\lambda_D^2)}\right]$$

$$\alpha = r\lambda_D b\lambda_P^2 b\lambda_P^1 f_P^3 f_P^2 f_P^1 I_c D_k \qquad B = r\lambda_D b\lambda_P^1 f_P^2 I_a D_k f_1^1$$

$$\beta = r\lambda_D b\lambda_P^2 b\lambda_P^1 f_P^3 f_P^2 f_P^1 I_a D_k \qquad C = b\lambda_D^1 f_D^2 r\lambda_D I_c D_k f_p^1$$

$$A = r\lambda_D b\lambda_P^1 f_P^2 r_c D_k f_1^1 \qquad D = b\lambda_D^1 f_D^2 r\lambda_D I_a D_k f_p^1$$

and $\lambda_{P,D}^n$ is the decay constant for the parent or daughter in the n^{th} compartment.

APPENDIX II

Contained below is a listing of the FORTRAN IV PAID code. In general, as described in the text, the code yields dose rates and doses to the lung, using the ICRP TGLD model, and any selected reference organ. The printout of a sample case is included.

A description of the input parameters, format, and options available is given below. An attempt has been made to keep the input as simple as possible and the program will run multiple cases if another set of input data is added. All of the data pertaining to the lung are set within the code based on reference (3).

Card 1

	One title card for identification of the problem.	20A4

Card 2

NTT	Number of times for which solutions are desired.	I10
IHG -1/0/+1	(Ingestion/Inhalation/Inhalation) case	I10
IFLAG -1/0/+1	(Omit/Print/Print) To supress output for lung compartments. Used for inhalation cases only.	I10

Card 3

LRP	Physical half-life (years) of the parent.	E12.5
LBP	Biological half-life (years) of the parent.	E12.5
F1PR	GI Tract to blood (f_1) fraction for the parent.	E12.5
F2PPR	Blood to reference organ (f_2') fraction for the parent.	E12.5
EPSPL	Average energy (meV) for the parent decay in the lung.	E12.5
EPSPR	Average energy (meV) for the parent decay in the reference organ.	E12.5

Card 4

(Same as card 3 but for daughter instead of parent.

Card 5

TIN(I)	Times for which solutions are required (years).	6E12.5

Card 6

IA	The acute intake (Ci)	E12.5
IC	The chronic intake (Ci/yr)	E12.5
UTA3	The deposition fractions	E12.5
UTA4	for the N-P, T-B and	E12.5
UTA5	P compartment respectively	E12.5
ØRGMR	Reference organ mass (g).	E12.5

Return to Card 1 for the next case.

SAMPLE CASE

PU-239/U-235 AEROSOL CONC. 1.0 (FCI/CUBIC METER AMAD=0.05 R.O.=LIVER

ACUTE INTAKE (CI)	CHRONIC INTAKE (CI/YR)	N - P DEPOSITION	T - B DEPOSITION	P DEPOSITION	REFERENCE ORGAN MASS (G)
0.0	8.32770E-12	1.00000E-03	8.00000E-02	5.90000E-01	1.80000E+03

FOR THE PARENT--

PHYSICAL HALF-LIFE (YEARS)	BIOLOGICAL HALF-LIFE (YEARS)	TRANSMISSION FRACTION (GIT-BLOOD)	TRANSMISSION FRACTION (BLOOD-R.O.)	AVERAGE ENERGY-LUNG (MEV)	AVERAGE ENERGY-R.O. (MEV)
2.44000D+04	4.00000D+01	1.00000E-04	4.50000E-01	5.15000E+00	5.15000E+00

FOR THE DAUGHTER--

PHYSICAL HALF-LIFE (YEARS)	BIOLOGICAL HALF-LIFE (YEARS)	TRANSMISSION FRACTION (GIT-BLOOD)	TRANSMISSION FRACTION (BLOOD-R.O.)	AVERAGE ENERGY-LUNG (MEV)	AVERAGE ENERGY-R.O. (MEV)
7.10000D+06	2.74000D-01	1.00000E-02	1.10000E-01	4.40000E+00	4.40000E+00

THE FOLLOWING CASE IS FOR UPTAKE DUE TO INHALATION.

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AT TIME 1.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	3.93312E-08	5.21315E-18	5.19660E-18	3.93937E-08	3.93312E-08

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	1.25992E-06	8.34120E-17	8.32796E-17	1.26092E-06	1.25992E-06

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
2.57801E-05	2.23527E-05	2.85821E-13	1.07341E-13	2.57801E-05	2.23527E-05

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.92202E-04	2.13152E-04	1.49313E-11	5.41047E-12	3.92202E-04	2.13152E-04

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT	PARENT	DAUGHTER	DAUGHTER	TOTAL	TOTAL

DOSE RATE	DOSE	DOSE RATE	DOSE	DOSE RATE	DOSE
8.40843E-04	2.98284E-04	4.52451E-11	1.19691E-11	8.40843E-04	2.98284E-04

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.01809E-04	3.53171E-05	5.36360E-12	1.44634E-12	1.01809E-04	3.53171E-05

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.58)	DAUGHTER DOSE RATE	DAUGHTER DOSE (1.66)	TOTAL DOSE RATE	TOTAL DOSE (0.58)
1.71491E-06	5.96853E-07	3.47688E-14	1.04372E-14	1.71491E-06	5.96853E-07

AT TIME 5.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	1.96906E-07	5.21315E-18	2.60492E-17	3.93937E-08	1.96906E-07

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	6.30359E-06	8.34120E-17	4.16927E-16	1.26092E-06	6.30359E-06

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.54360E-05	1.50893E-04	2.19222E-12	5.38419E-12	3.54360E-05	1.50893E-04

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.07419E-04	3.13829E-03	1.16653E-10	2.85694E-10	9.07419E-04	3.13829E-03

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
8.67108E-03	1.92681E-02	2.00876E-09	3.29601E-09	8.67108E-03	1.92681E-02

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.50491E-03	2.93922E-03	3.15821E-10	4.76682E-10	1.50491E-03	2.93922E-03

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.16)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.68)	TOTAL DOSE RATE	TOTAL DOSE (0.16)
3.68285E-05	6.43889E-05	1.27893E-12	2.09867E-12	3.68285E-05	6.43889E-05

AT TIME 10.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	3.93875E-07	5.21315E-18	5.21150E-17	3.93937E-08	3.93875E-07

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	1.26082E-05	8.34120E-17	8.33987E-16	1.26092E-06	1.26082E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.67897E-05	3.32751E-04	2.93097E-12	1.87231E-11	3.67897E-05	3.32751E-04

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.79649E-04	7.92503E-03	1.56071E-10	9.95832E-10	9.79649E-04	7.92503E-03

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.42583E-02	7.89133E-02	5.30992E-09	2.20530E-08	1.42583E-02	7.89133E-02

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.80168E-03	1.61402E-02	1.20973E-09	4.14608E-09	3.80168E-03	1.61402E-02

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.10)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.37)	TOTAL DOSE RATE	TOTAL DOSE (0.10)
1.16482E-04	4.38825E-04	4.17767E-12	1.54630E-11	1.16482E-04	4.38825E-04

AT TIME 15.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	5.90844E-07	5.21315E-18	7.81807E-17	3.93937E-08	5.90844E-07

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	1.89127E-05	8.34120E-17	1.25105E-15	1.26092E-06	1.89127E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.68976E-05	5.17073E-04	3.03486E-12	3.37230E-11	3.68976E-05	5.17073E-04

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.85406E-04	1.28432E-02	1.61614E-10	1.79460E-09	9.85406E-04	1.28432E-02

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.60859E-02	1.55668E-01	7.14067E-09	5.37807E-08	1.60859E-02	1.55668E-01

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
6.16126E-03	4.10425E-02	2.30476E-09	1.28925E-08	6.16126E-03	4.10425E-02

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.08)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.26)	TOTAL DOSE RATE	TOTAL DOSE (0.08)
2.05681E-04	1.24387E-03	7.29602E-12	4.41827E-11	2.05681E-04	1.24387E-03

AT TIME 20.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	7.87812E-07	5.21315E-18	1.04247E-16	3.93937E-08	7.87812E-07

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT	PARENT	DAUGHTER	DAUGHTER	TOTAL	TOTAL

DOSE RATE	DOSE	DOSE RATE	DOSE	DOSE RATE	DOSE
1.26092E-06	2.52173E-05	8.34120E-17	1.66811E-15	1.26092E-06	2.52173E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.69062E-05	7.01590E-04	3.04673E-12	4.89372E-11	3.69062E-05	7.01590E-04

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.85865E-04	1.77718E-02	1.62248E-10	2.60480E-09	9.85865E-04	1.77718E-02

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.66217E-02	2.37709E-01	7.90025E-09	9.16817E-08	1.66218E-02	2.37709E-01

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
8.52554E-03	7.77592E-02	3.45426E-09	2.72793E-08	8.52554E-03	7.77592E-02

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.07)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.20)	TOTAL DOSE RATE	TOTAL DOSE (0.07)
2.92287E-04	2.49088E-03	1.02395E-11	8.81170E-11	2.92287E-04	2.49088E-03

AT TIME 30.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	1.18175E-06	5.21315E-18	1.56378E-16	3.93937E-08	1.18175E-06

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	3.78265E-05	8.34120E-17	2.50223E-15	1.26092E-06	3.78265E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.69069E-05	1.07066E-03	3.04808E-12	7.94152E-11	3.69069E-05	1.07066E-03

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.85905E-04	2.76308E-02	1.62320E-10	4.22785E-09	9.85905E-04	2.76308E-02

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.68179E-02	4.05282E-01	8.27811E-09	1.73193E-07	1.68179E-02	4.05282E-01

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.32539E-02	1.86658E-01	5.78689E-09	7.34712E-08	1.32539E-02	1.86658E-01

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.06)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.15)	TOTAL DOSE RATE	TOTAL DOSE (0.06)
4.47541E-04	6.21106E-03	1.54289E-11	2.17215E-10	4.47541E-04	6.21106E-03

AT TIME 40.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	1.57569E-06	5.21315E-18	2.08510E-16	3.93937E-08	1.57569E-06

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	5.04357E-05	8.34120E-17	3.33635E-15	1.26092E-06	5.04357E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.69069E-05	1.43973E-03	3.04809E-12	1.09896E-10	3.69069E-05	1.43973E-03

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.85905E-04	3.74898E-02	1.62321E-10	5.85105E-09	9.85905E-04	3.74898E-02

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.68336E-02	5.73569E-01	8.32140E-09	2.56265E-07	1.68336E-02	5.73570E-01

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.79810E-02	3.42834E-01	8.12620E-09	1.43036E-07	1.79810E-02	3.42834E-01

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.06)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.12)	TOTAL DOSE RATE	TOTAL DOSE (0.06)
5.78664E-04	1.13609E-02	1.97863E-11	3.93923E-10	5.78664E-04	1.13609E-02

AT TIME 50.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	1.96962E-06	5.21315E-18	2.60641E-16	3.93937E-08	1.96962E-06

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FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	6.30449E-05	8.34120E-17	4.17046E-15	1.26092E-06	6.30449E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.69069E-05	1.80880E-03	3.04809E-12	1.40377E-10	3.69069E-05	1.80880E-03

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.85905E-04	4.73489E-02	1.62321E-10	7.47426E-09	9.85905E-04	4.73489E-02

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.68349E-02	7.41914E-01	8.32590E-09	3.39510E-07	1.68349E-02	7.41914E-01

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
2.27068E-02	5.46274E-01	1.04661E-08	2.35997E-07	2.27068E-02	5.46274E-01

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.06)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.11)	TOTAL DOSE RATE	TOTAL DOSE (0.06)
6.88946E-04	1.77149E-02	2.34480E-11	6.10624E-10	6.88946E-04	1.77149E-02

AT TIME 70.00 YEARS, DOSE RATES (RADS/YR) AND DOSES (RADS) ARE--

FOR THE NASOPHYRINGIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.93937E-08	2.75750E-06	5.21315E-18	3.64904E-16	3.93937E-08	2.75750E-06

FOR THE TRACHEOBRONCHIAL COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.26092E-06	8.82632E-05	8.34120E-17	5.83870E-15	1.26092E-06	8.82632E-05

FOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEARANCE FROM PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.69069E-05	2.54693E-03	3.04809E-12	2.01339E-10	3.69069E-05	2.54693E-03

FOR THE PULMONARY COMPARTMENT

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
9.85905E-04	6.70670E-02	1.62321E-10	1.07207E-08	9.85905E-04	6.70670E-02

FOR THE LYMPH NODES, TRANSMITTED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
1.68350E-02	1.07861E+00	8.32639E-09	5.06036E-07	1.68350E-02	1.07861E+00

FOR THE LYMPH NODES, RETAINED FRACTION

PARENT DOSE RATE	PARENT DOSE	DAUGHTER DOSE RATE	DAUGHTER DOSE	TOTAL DOSE RATE	TOTAL DOSE
3.21542E-02	1.09489E+00	1.51458E-08	4.92116E-07	3.21543E-02	1.09489E+00

FOR THE REFERENCE ORGAN, PARENTHESES INDICATE PERCENT OF TOTAL DOSE VIA GI TRACT

PARENT DOSE RATE	PARENT DOSE (0.06)	DAUGHTER DOSE RATE	DAUGHTER DOSE (0.10)	TOTAL DOSE RATE	TOTAL DOSE (0.06)
8.59609E-04	3.32990E-02	2.91139E-11	1.13951E-09	8.59609E-04	3.32990E-02

END OF CASE

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0001              REAL    IA,IC
0002              REAL * 8          LTP1,LTD1,LRP,LBP,LRD,LBD,LTP2,LTD2,LTP3,LTD3,
                 1  NPT1,NPT2,NPT3,NDT1,NDT2,NDT3,IPT1,IPT2,IPT3,IDT1,IDT2,IDT3
0003              REAL * 8          P12,P13,P23,P21,P31,P32,P1D1,P1D2,P1D3,P2D1,
                 1  P2D2,P2D3,P3D1,P3D2,P3D3,D1P1,D2P2,D3P1,D1P2,D3P2,D1P3,D2P3,
                 2  D3P3,D2P1,D12,D13,D21,D23,D31,D32
0004              REAL * 8  B1D,B2D,B3D,A2D,A3D,A4D,D1D,D2D,D3D,C2D,C3D,C4D
0005              REAL * 8  BE1,BE2,BE3,BE4,AL2,AL3,AL4,AL5,B1,B2,B3,B4,A2,A3,A4,A5,
                 1D1,D2,D3,D4,C2,C3,C4,C5
0006              REAL * 8  NPT2R,NDT2R,IPT2R,IDT2R,B1DR,B2DR,B3DR,A2DR,A3DR,A4DR,        R
                 1D1DR,D2DR,D3DR,C2DR,C3DR,C4DR,P12R,P21R
0007              REAL * 8          LB,Z,ODP,DPLN2
0008              DIMENSION  DX(10),LB(15),FD(15),ORGM(15),HOLL(20),TIN(25)
                C
                C     THIS PROGRAM REPRESENTS THE ICRP TGLD LUNG MODEL MODIFIED BY ICRP-19.
                C     IT USES SUB-CHAINS CONSISTING OF  1. A LUNG COMPARTMENT (A-H),
                C     2. FOR A-G, THE REFERENCE ORGAN.  FOR H, THE LYMPH NODES.
                C     3.   FOR H ONLY, THE REFERENCE ORGAN.
                C     THE PROGRAM ALLOWS THE PARENT AND ONE DAUGHTER TO BE CALCULATED.
                C
                C
                C     CARDS WITH A CTB WERE ADDED TO GET P/T-B CLEARANCE DOSE.
                C     CARDS WITH AN R WERE ADDED TO GET LYMPH NODE RETENTION DOSE.
                C
0009             50 READ (5,155,END=800) (HOLL(K),K=1,20)
0010            275 FORMAT(3I10)
0011            100 READ (5,275) NTT,IHG,IFLAG
0012            155 FORMAT(20A4)
0013                WRITE(6,255) (HOLL(K),K=1,20)
0014            255 FORMAT(1H1,24X,20A4///)
0015            355 FORMAT(6E12.5)
0016                READ (5,355) LRP,LBP,F1PR,F2PPR,EPSPL,EPSPR
0017                READ (5,355) LRD,LBD,F1DR,F2PDR,EPSDL,EPSDR
0018                READ (5,355) (TIN(I),I=1,NTT)
0019                READ (5,355) IA,IC,UTA3,UTA4,UTA5,ORGMR
0020                WRITE(6,305)
0021            305 FORMAT(1H ,12X,5HACUTE,15X,7HCHRONIC,14X,5HN - P,15X,5HT - B,17X,1
                   1HP,14X,9HREFERENCE/9X,11HINTAKE (CI),9X,14HINTAKE (CI/YR),8X,10HDE
                   2POSITION,10X,10HDEPOSITION,10X,10HDEPOSITION,7X,14HORGAN MASS (G))
0022                WRITE(6,315)IA,IC,UTA3,UTA4,UTA5,ORGMR
0023            315 FORMAT(1PE21.5,1PE20.5,1PE21.5,1PE20.5,1P2E19.5//)
0024                WRITE(6,310)
0025            310 FORMAT(1H ,25X,16HFOR THE PARENT--/)
0026                WRITE(6,320)
0027            320 FORMAT(1H ,11X,8HPHYSICAL,11X,10HBIOLOGICAL,9X,12HTRANSMISSION,8X,
                   112HTRANSMISSION,9X,9H AVERAGE ,11X,9H AVERAGE /10X,9HHALF-LIFE,12X
                   2,9HHALF-LIFE,11X,8HFRACTION,12X,8HFRACTION,11X,11HENERGY-LUNG,9X,1
                   31HENERGY-R.O./12X,7H(YEARS),13X,7H(YEARS),12X,11H(GIT-BLOOD),8X,12
                   4H(BLOOD-R.O.),11X,5H(MEV),15X,5H(MEV))
0028                WRITE(6,315)LRP,LBP,F1PR,F2PPR,EPSPL,EPSPR
0029                WRITE(6,325)
0030            325 FORMAT(1H ,25X,18HFOR THE DAUGHTER--/)
0031                WRITE(6,320)
0032                WRITE(6,315)LRD,LBD,F1DR,F2PDR,EPSDL,EPSDR
0033                DX(1)=UTA3
0034                DX(2)=UTA4
0035                DX(3)=UTA5
0036                DX(4)=UTA3
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0037              DX(5)=UTA4
0038              DX(6)=UTA5
0039              DX(7)=UTA5
0040              DX(8)=UTA5
0041              LB(1)=2.74D-5
0042              LB(2)=2.74D-5
0043              LB(3)=1.37D+0
0044              LB(4)=1.1D-3
0045              LB(5)=5.5D-4
0046              LB(6)=2.7D-3
0047              LB(7)=1.37D+0
0048              LB(8)=1.37D+0
0049              LB(9)=2.74D+0
0050              FD(1)=0.01D+0
0051              FD(2)=0.01D+0
0052              FD(3)=0.05D+0
0053              FD(4)=0.99D+0
0054              FD(5)=0.99D+0
0055              FD(6)=0.4D+0
0056              FD(7)=0.4D+0
0057              FD(8)=0.15D+0
0058              FD(9)=0.9D+0
0059              ORGM(1)=32.0
0060              ORGM(2)=40.0
0061              ORGM(3)=570.0
0062              ORGM(4)=32.0
0063              ORGM(5)=40.0
0064              ORGM(6)=570.0
0065              ORGM(7)=570.0
0066              ORGM(8)=570.0
0067              ORGM(9)=15.0
0068              TEFF = 0.0039                                          CTB
0069              OMTB=ORGM(2)                                           CTB
0070              ODP=1.0D+0
0071              DPLN2=6.93D-1
0072              CON=1.87E+10
0073              LRP=DPLN2/LRP
0074              LBP=DPLN2/LBP
0075              LRD=DPLN2/LRD
0076              LBD=DPLN2/LBD
0077              DO 400 K=1,9
0078          400 LB(K)=DPLN2/LB(K)
0079              IF(IHG.GT.0) WRITE(6,360)
0080              IF(IHG.LT.0) WRITE(6,365)
0081          360 FORMAT(1H ,40X,51HTHE FOLLOWING CASE IS FOR UPTAKE DUE TO INHALATI
                  1ON.//)
0082          365 FORMAT(1H ,40X,50HTHE FOLLOWING CASE IS FOR UPTAKE DUE TO INGESTIO
                  1N.//)
              C     START EACH TIME LOOP
0083              DO 700 NT=1,NTT
0084              T=TIN(NT)
0085              IF(T.LT.0.0) GO TO 700
0086              WRITE(6,455) T
0087          455 FORMAT(1H ,5X,7HAT TIME,F6.2,1X,50HYEARS, DOSE RATES (RADS/YR) AND
                  1 DOSES (RADS) ARE--/)
0088              Z=T
0089              DRPNP=0.0
0090              DRDNP=0.0
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0091            DRPTB=0.0
0092            DRDTB=0.0
0093            DRPP=0.0
0094            DRDP=0.0
0095            DRPL=0.0
0096            DRDL=0.0
0097            DRPRO=0.0
0098            DRDRO=0.0
0099            DPNP=0.0
0100            DDNP=0.0
0101            DPTB=0.0
0102            DDTB=0.0
0103            DPP=0.0
0104            DDP=0.0
0105            DPL=0.0
0106            DDL=0.0
0107            DPRO=0.0
0108            DDRO=0.0
0109            DPGIT=0.0
0110            DDGIT=0.0
0111            QLPCTB=0.0
0112            QUPCTB=0.0                                              CTB
0113            QLDCTB=0.0                                              CTB
0114            QUDCTB=0.0                                              CTB
0115            JT=8
0116            IF(IHG.LT.0) JT=1
                C   START EACH SUB-COMPARTMENT CHAIN
0117            DO 600 J=1,JT
                C   DX(J) SET OUTSIDE LOOP.
                C   WHOLE PROGRAM PREDICATED ON PARENT AND DAUGHTER BEING CLASS Y.
0118            DK=DX(J)
0119            LTP1=LRP+LB(J)
0120            IF(IHG.LT.0) LTP1=LRP+LBP
0121            LTD1=LRD+LB(J)
0122            IF(IHG.LT.0) LTD1=LRD+LBD
0123            LTP2=LRP+LB(J+1)
0124            LTD2=LRD+LB(J+1)
0125            LTP3=LRP+LPP
0126            LTD3=LRD+LBD
0127            IF(J.LT.8)LTP2=LRP+LBP
0128            IF(J.LT.8)LTD2=LRD+LBD
                C   NOW SET ORGAN MASSES.
0129            OMAS=ORGM(J)
0130            IF(IHG.LT.0) OMAS=ORGMR
0131            TMAS=ORGMR
0132            THMAS=ORGMR
0133            IF(J.EQ.8)TMAS=ORGM(J+1)
0134            FL=FD(J)
0135            F2PP=F2PPR
0136            IF(J.EQ.8) F2PP = 1.0
0137            F1P=F1PR
0138            F2PD=F2PDR
0139            IF(J.EQ.8) F2PD = 1.0
0140            F1D=F1DR
0141            FP2=1.0
0142            IF(J.EQ.8)FP2=FD(J+1)
0143            FD2=1.0
0144            IF(J.EQ.8)FD2=FD(J+1)
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0145                FP3=1.0
0146                FD3=1.0
                C   SET F2P AND F1 FOR BLOOD AND GIT.  J=1,2,3,8 ARE BLOOD ONLY.
                C   J=4,5,6,7 ARE BLOOD AND GIT (F2P*F1) BOTH.
0147                IF(J.LE.3.OR.J.EQ.8) F1P=1.0
0148                IF(J.LE.3.OR.J.EQ.8) F1D=1.0
                C   DO ALL PARAMETERS IN EQUATIONS.
0149                NPT1=0.0D+0
0150                IF(LTP1*Z.GT.88.0D+0) GO TO 460
0151                NPT1 =DEXP(-LTP1*Z)
0152              460 CONTINUE
0153                NPT2=0.0D+0
0154                IF(LTP2*Z.GT.88.0D+0) GO TO 470
0155                NPT2 =DEXP(-LTP2*Z)
0156              470 CONTINUE
0157                NPT2R=0.0D+0                                          CYB
0158                IF(LRP*Z.GT.88.0D+0) GO TO 463                        CTB
0159                NPT2R=DEXP(-LRP*Z)                                    CTB
0160              463 CONTINUE                                            CTB
0161                NPT3=0.0D+0
0162                IF(LTP3*Z.GT.88.0D+0) GO TO 480
0163                NPT3 =DEXP(-LTP3*Z)
0164              480 CONTINUE
0165                NDT1=0.0D+0
0166                IF(LTD1*Z.GT.88.0D+0) GO TO 465
0167                NDT1 =DEXP(-LTD1*Z)
0168              465 CONTINUE
0169                NDT2=0.0D+0
0170                IF(LTD2*Z.GT.88.0D+0) GO TO 475
0171                NDT2 =DEXP(-LTD2*Z)
0172              475 CONTINUE
0173                NDT2R=0.0D+0                                          CTB
0174                IF(LRD*Z.GT.88.0D+0) GO TO 473                        CTB
0175                NDT2R=DEXP(-LRD*Z)                                    CTB
0176              473 CONTINUE                                            CTB
0177                IF(LTD3*Z.GT.88.0D+0) GO TO 485
0178                NDT3 =DEXP(-LTD3*Z)
0179                NDT3=0.0D+0
0180              485 CONTINUE
0181                IPT1 = ODP - NPT1
0182                IPT2 = ODP - NPT2
0183                IPT2R = ODP - NPT2R                                   CTB
0184                IPT3 = ODP - NPT3
0185                IDT1 = ODP - NDT1
0186                IDT2 = ODP - NDT2
0187                IDT2R = ODP - NDT2R                                   CTB
0188                IDT3 = ODP - NDT3
0189                P12 = -LTP1 + LTP2
0190                P12R = -LTP1 + LRP                                      R
0191                P21R = -P12R                                            R
0192                P13 = -LTP1 + LTP3
0193                P23 = -LTP2 + LTP3
0194                P21 = -P12
0195                P31 = -P13
0196                P32 = -P23
0197                P1D1 = -LRP+LRD
0198                IF(IHG.LT.0) P1D1=-LTP1+LTD1
0199                P1D2 = -LTP1 + LTD2
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0200              P1D3 = -LTP1 + LTD3
0201              P2D1 = -LTP2 + LTD1
0202              P2D2 = -LTP2+LTD2
0203              IF(J.EQ.8) P2D2 = -LRP+LRD
0204              P2D3 = -LTP2 + LTD3
0205              P3D1 = -LTP3 + LTD1
0206              P3D2 = -LTP3 + LTD2
0207              P3D3 = -LTP3+LTD3
0208              D1P1 = -P1D1
0209              D2P1 = -P1D2
0210              D3P1 = -P1D3
0211              D1P2 = -P2D1
0212              D2P2 = -P2D2
0213              D3P2 = -P2D3
0214              D1P3 = -P3D1
0215              D2P3 = -P3D2
0216              D3P3 = -P3D3
0217              D12 = -LTD1 + LTD2
0218              D13 = -LTD1 + LTD3
0219              D21 = -D12
0220              D23 = -LTD2 + LTD3
0221              D31 = -D13
0222              D32 = -D23
                C     PARENT ACTIVITY IN FIRST SUB-COMPARTMENT.
0223              CONA = IA*DK*FL
0224              CONC = IC*DK*FL
0225              IF(IHG.LT.0) CONA=IA*F1PR*F2PPR
0226              IF(IHG.LT.0) CONC=IC*F1PR*F2PPR
0227              QLPA1 = CONA*NPT1
0228              QLPC1 = CONC*(IPT1/LTP1)
0229              QUPA1 = CONA*(IPT1/LTP1)
0230              QUPC1 = CONC*(( Z /LTP1)+(IPT1/(-LTP1*LTP1)))
0231              IF(J.LT.6.OR.J.GT.7) GO TO 505
0232              QLPCTB=QLPCTB+TEFF*LB(J)*(QLPA1+QLPC1)                          CTB
0233              QUPCTB=QUPCTB+TEFF*LB(J)*(QUPA1+QUPC1)                          CTB
0234            505 CONTINUE
0235              IF(J.EQ.8) DRPCTB=CON*(EPSPL/OMTB)*QLPCTB                       CTB
0236              IF(J.EQ.8) DPCTB=CON*(EPSPL/OMTB)*QUPCTB                        CTB
0237              IF(IHG.LT.0) EPSPL=EPSPR
0238              DRP1 = CON*(EPSPL/OMAS)*(QLPA1+QLPC1)
0239              DP1 = CON*(EPSPL/OMAS)*(QUPA1+QUPC1)
0240              IF(IHG.LT.0) GO TO 333
                C     PARENT IN SECOND SUB-COMPARTMENT.
0241              CONA=CONA*LB(J)*EP2*F1P*F2PP
0242              CONC=CONC*LB(J)*EP2*F1P*F2PP
0243              QLPA2=CONA*((NPT1/P12)+(NPT2/P21))
0244              QLPC2=CONC*((ODP/(LTP1*LTP2))+(NPT1/(-LTP1*P12))+(NPT2/(-LTP2*P21)
                 1))
0245              QUPA2=CONA*((IPT1/(LTP1*P12))+(IPT2/(-TP2*P21)))
0246              QUPC2=CONC*((Z/(LTP1*LTP2))+(IPT1/(-LTP1*LTP1*P12))+(IPT2/(-LTP2*L
                 1TP2*P21)))
0247              EPV=EPSPR
0248              IF(J.EQ.8) EPV=EPSPL
0249              IF(J.NE.8) GO TO 558                                            R
0250              CDARET=(CONA/EP2)*(1.0-EP2)
0251              CDCRET=(CONC/EP2)*(1.0-EP2)
0252              QLPA2R=CDARET*((NPT1/P12R)+(NPT2R/P21R))                        R
0253              QLPC2R=CDCRET*((ODP/(LTP1*LRP))+(NPT1/(-LTP1*P12R))+(NPT2R/(-LRP*P      R
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                121R)))                                                                 R
0254                QUPA2R=CDARET*((IPT1/(LTP1*P12R))+(IPT2R/(LRP*P21R)))               R
0255                QUPC2R=CDCRET*((Z/(LTP1*LRP))+(IPT1/(-LTP1*LTP1*P12R))+(IPT2R/(-LR  R
               1P*LRP*P21R)))                                                           R
0256                DRP2R=CON*(EPSPL/TMAS)*(QLPA2R+QLPC2R)                              R
0257                DP2R=CON*(EPSPL/TMAS)*(QUPA2R+QUPC2R)                               R
0258              558 CONTINUE                                                          R
0259                DRP2=CON*(EPV/TMAS)*(QLPA2+QLPC2)
0260                DP2=CON*(EPV/TMAS)*(QUPA2+QUPC2)
                C       THIRD SUB-COMPARTMENT.  ONLY USE IF LYMPH NODES IN CHAIN.
0261                QLPA3 = 0.0
0262                QLPC3 = 0.0
0263                QUPA3 = 0.0
0264                QUPC3 = 0.0
0265                DRP3=0.0
0266                DP3=0.0
0267                IF(J.NE.8) GO TO 333
0268                CONA=CONA*LB(J+1)*F1P*F2PPR
0269                CONC=CONC*LB(J+1)*F1P*F2PPR
0270                QLPA3=CONA*((NPT1/(P12*P13))+(NPT2/(P21*P23))+(NPT2/(P31*P32)))
0271                QLPC3=CONC*((ODP/(LTP1*LTP2*LTP3))+(NPT1/(-LTP1*P12*P13))+(NPT2/(-
               1LTP2*P21*P23))+(NPT3/(-LTP3*P31*P32)))
0272                QUPA3=CONA*((IPT1/(LTP1*P12*P13))+(IPT2/(LTP2*P21*P23))+(IPT3/(LTP
               13*P31*P32)))
0273                QUPC3=CONC*((Z/(LTP1*LTP2*LTP3))+(IPT1/(-LTP1*LTP1*P12*P13))+(IPT2
               1/(-LTP2*LTP2*P21*P23))+(IPT3/(-LTP3*LTP3*P31*P32)))
0274                DRP3=CON*(EPSPP/THMAS)*(QLPA3+QLPC3)
0275                DP3=CON*(EPSPP/THMAS)*(QUPA3+QUPC3)
                C
                C       END ALL PARENT (THREE SUB-COMPARTMENT CHAIN LIMIT).
                C
0276              333 CONTINUE
                C       DAUGHTER IN FIRST SUB-COMPARTMENT.
0277                CONAR=IA*DK*FL*LRD
0278                CONCR=IC*DK*FL*LRD
0279                IF(IHG.LT.0) CONAR=IA*LRD*F1PR*F2PPR
0280                IF(IHG.LT.0) CONCR=IC*LRD*F1PR*F2PPR
0281                QLDA1=CONAR*((NPT1/P1D1)+(NDT1/D1P1))
0282                QLDC1=CONCR*((ODP/(LTP1*LTD1))+(NPT1/(-LTP1*P1D1))+(NDT1/(-LTD1*P1
               1P1)))
0283                QUDA1=CONAR*((IPT1/(LTP1*P1D1))+(IDT1/(LTD1*D1P1)))
0284                QUDC1=CONCR*((Z/(LTP1*LTD1))+(IPT1/(-LTP1*LTP1*P1D1))+(IDT1/(-LTD1
               1*LTD1*D1P1)))
0285                IF(J.LT.6.OR.J.GT.7) GO TO 605                                      CTB
0286                QLDCTB=QLDCTB+TEFF*LB(J)*(QLDA1+QLDC1)                              CTB
0287                QUDCTB=QUDCTB+TEFF*LB(J)*(QUDA1+QUDC1)                              CTB
0288              605 CONTINUE
0289                IF(J.EQ.8) DRDCTB=CON*(EPSDL/DMTB)*QLDCTB                           CTB
0290                IF(J.EQ.8) DDCTB=CON*(EPSDL/DMTB)*QUDCTB                            CTB
0291                IF(IHG.LT.0) EPSDL=EPSDR
0292                DRD1=CON*(EPSDL/DMAS)*(QLDA1+QLDC1)
0293                DD1=CON*(EPSDL/DMAS)*(QUDA1+QUDC1)
0294                IF(IHG.LT.0) GO TO 444
                C       DAUGHTER IN SECOND SUB-COMPARTMENT.
0295                A=IC*DK*FL*LRD*LB(J)*FP2*F1P*F2PP
0296                B=IA*DK*FL*LRD*LB(J)*FP2*F1P*F2PP
0297                C=IC*DK*FL*LB(J)*LRD*FD2*F1D*F2PD
0298                D=IA*DK*FL*LB(J)*LRD*FD2*F1D*F2PD
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0299              B1D=P12*P1D2
0300              B2D=P21*P2D2
0301              B3D=D2P1*D2P2
0302              A2D=-LTP1*B1D
0303              A3D=-LTP2*B2D
0304              A4D=-LTD2*B3D
0305              D1D=P1D1*P1D2
0306              D2D=D1P1*D12
0307              D3D=D2P1*D21
0308              C2D=-LTP1*D1D
0309              C3D=-LTD1*D2D
0310              C4D=-LTD2*D3D
0311              IF(J.NE.8) GO TO 337                                                    R
0312              B1DR=P12*(-LTP1+LRD)                                                    R
0313              B2DR=P21*(-LTP2+LRD)                                                    R
0314              B3DR=(-LRD+LTP1)*(-LRD+LTP2)                                            R
0315              A2DR=-LTP1*B1DR                                                         R
0316              A3DR=-LTP2*B2DR                                                         R
0317              A4DR=-LRD*B3DR                                                          R
0318              D1DR=P1D1*(-LTP1+LRD)                                                   R
0319              D2DR=D1P1*(-LTD1+LRD)                                                   R
0320              D3DR=(-LRD+LTP1)*(-LRD+LTD1)                                            R
0321              C2DR=-LTP1*D1DR                                                         R
0322              C3DR=-LTD1*D2DR                                                         R
0323              C4DR=-LRD*D3DR                                                          R
0324            337 CONTINUE
0325              QLA=A*((ODP/(LTP1*LTP2*LTD2))+(NPT1/A2D)+(NPT2/A3D)+(NDT2/A4D))
0326              QLB=B*((NPT1/B1D)+(NPT2/B2D)+(NDT2/B3D))
0327              QLC=C*((ODP/(LTP1*LTD1*LTD2))+(NPT1/C2D)+(NDT1/C3D)+(NDT2/C4D))
0328              QLD=D*((NPT1/D1D)+(NDT1/D2D)+(NDT2/D3D))
0329              QLDA2=QLB+QLD
0330              QLDC2=QLA+QLC
0331              QUA=A*((Z/(LTP1*LTP2*LTD2))+(IPT1/(LTP1*A2D))+(IPT2/(LTP2*A3D))+(I
                 1DT2/(LTD2*A4D)))
0332              QUB=B*((IPT1/A2D)+(IPT2/A3D)+(IDT2/A4D))
0333              QUC=C*((Z/(LTP1*LTD1*LTD2))+(IPT1/(LTP1*C2D))+(IDT1/(LTD1*C3D))+(I
                 1DT2/(LTD2*C4D)))
0334              QUD=D*((IPT1/C2D)+(IDT1/C3D)+(IDT2/C4D))
0335              QUDA2=QUB+QUD
0336              QUDC2=QUA+QUC
0337              EPU=EPSDR
0338              IF(J.EQ.8) EPU=EPSDL
0339              IF(J.NE.8) GO TO 658                                                    R
0340              AR=IC*DK*FL*LRD*LB(J)*(1.0-FP2)*F1P*F2PP                                R
0341              BR=IA*DK*FL*LRD*LB(J)*(1.0-FP2)*F1P*F2PP                                R
0342              CR=IC*DK*FL*LB(J)*LRD*(1.0-FD2)*F1D*F2PD                                R
0343              DR=IA*DK*FL*LB(J)*LRD*(1.0-FD2)*F1D*F2PD                                R
0344              QLAR=AR*((ODP/(LTP1*LTP2*LRD))+(NPT1/A2DR)+(NPT2/A3DR)+(NDT2R/A4DR      R
                 1))                                                                     R
0345              QLBR=BR*((NPT1/B1DR)+(NPT2/B2DR)+(NDT2R/B3DR))                          R
0346              QLCR=CR*((ODP/(LTP1*LTD1*LRD))+(NPT1/C2DR)+(NDT1/C3DR)+(NDT2R/C4DR      R
                 1))                                                                     R
0347              QLDR=DR*((NPT1/D1DR)+(NDT1/D2DR)+(NDT2R/D3DR))                          R
0348              QLDA2R=QLBR+QLDR                                                        R
0349              QLDC2R=QLAR+QLCR                                                        R
0350              QUAR=AR*((Z/(LTP1*LTP2*LRD))+(IPT1/(LTP1*A2DR))+(IPT2/(LTP2*A3DR))      R
                 1+(IDT2R/(LRD*A4DR)))                                                   R
0351              QUBR=BR*((IPT1/A2DR)+(IPT2/A3DR)+(IDT2R/A4DR))                          R
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0352              QUCR=CR*((Z/(LTP1*LTD1*LRD))+(IPT1/(LTP1*C2DR))+(IDT1/(LTD1*C3DR))  R
                 1+(IDT2R/(LRD*C4DR)))                                                R
                  QUDR=DR*((IPT1/C2DR)+(IDT1/C3DR)+(IDT2R/C4DR))                      R
0353              QUDA2R=QUBR+QUDR                                                    R
0354              QUDC2R=QUAR+QUCR                                                    R
0355              DRD2R=CON*(EPSDL/TMAS)*(QLDA2R+QLDC2R)                              R
0356              DD2R=CON*(EPSDL/TMAS)*(QUDA2R+QUDC2R)                               R
0357           458 CONTINUE                                                           R
0358              DRD2=CON*(EPU/TMAS)*(QLDA2+QLDC2)
0359              DD2=CON*(EPU/TMAS)*(QUDA2+QUDC2)
0360        C     END ALL DAUGHTER ACTIVITY USING EPSD.
            C     DAUGHTER IN THIRD SUB-COMPARTMENT.
0361              QLAL=0.0
0362              QLAP=0.0
0363              QLBP=0.0
0364              QLCP=0.0
0365              QLDP=0.0
0366              QLDA3=0.0
0367              QLDC3=0.0
0368              QUAL=0.0
0369              QUAP=0.0
0370              QUBP=0.0
0371              QUAP=0.0
0372              QUBP=0.0
0373              QUCP=0.0
0374              QUDP=0.0
0375              QUDA3=0.0
0376              QUDC3=0.0
0377              DRD3=0.0
0378              DD3=0.0
0379              IF(J.NE.8) GO TO 444
0380              AL=IC*DK*FL*FP2*FP3*LB(J)*LB(J+1)*LRD*F2PPR
0381              BE=IA*DK*FL*FP2*FP3*LB(J)*LB(J+1)*LRD*F2PPR
0382              AP=LB(J+1)*FD3*A*F2PDR
0383              BP=LB(J+1)*FD3*B*F2PDR
0384              CP=LB(J+1)*FD3*C*F2PDR
0385              DP=LB(J+1)*FD3*D*F2PDR
0386              BE1=P12*P13*P1D3
0387              BE2=P21*P23*P2D3
0388              BE3=P31*P32*P3D3
0389              BE4=D3P1*D3P2*D3P3
0390              AL2=-LTP1*BE1
0391              AL3=-LTP2*BE2
0392              AL4=-LTP3*BE3
0393              AL5=-LTD3*BE4
0394              B1=B1D*P1D3
0395              B2=B2D*P2D3
0396              B3=B3D*D23
0397              B4=D3P1*D3P2*D32
0398              A2=-LTP1*B1
0399              A3=-LTP2*B2
0400              A4=-LTD2*B3
0401              A5=-LTD3*B4
0402              D1=D1D*P1D3
0403              D2=D2D*D13
0404              D3=D3D*D23
0405              D4=D3P1*D31*D32
0406              C2=-LTP1*D1
```

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0407              C3=-LTD1*D2
0408              C4=-LTD2*D3
0409              C5=-LTD3*D4
0410              QLAL=AL*((DDP/(LTP1*LTP2*LTP3*LTD3))+(NPT1/AL2)+(NPT2/AL3)+(NPT3/A
                 1L4)+(NDT3/AL5))
0411              QLBE=BE*((NPT1/BE1)+(NPT2/BE2)+(NPT3/BE3)+(NDT3/BE4))
0412              QLAP=AP*((DDP/(LTP1*LTP2*LTD2*LTD3))+(NPT1/A2)+(NPT2/A3)+(NDT2/A4)
                 1+(NDT3/A5))
0413              QLBP=BP*((NPT1/B1)+(NPT2/B2)+(NDT2/B3)+(NDT3/B4))
0414              QLCP=CP*((DDP/(LTP1*LTD1*LTD2*LTD3))+(NPT1/C2)+(NDT1/C3)+(NDT2/C4)
                 1+(NDT3))
0415              QLDP=DP*((NPT1/D1)+(NDT1/D2)+(NDT2/D3)+(NDT3/D4))
0416              QLDA3=QLBE+QLBP+QLDP
0417              QLDC3=QLAL+QLAP+QLCP
0418              QUAL=AL*((Z/(LTP1*LTP2*LTP3*LTD3))+(IPT1/(LTP1*AL2))+(IPT2/(LTP2*A
                 1L3))+(IPT3/(LTP3*AL4))+(IDT3/(LTD3*AL5)))
0419              QUBE=BE*((IPT1/(LTP1*BE1))+(IPT2/(LTP2*BE2))+(IPT3/(LTP3*BE3))+(ID
                 1T3/(LTD3*BE4)))
0420              QUAP=AP*((Z/(LTP1*LTP2*LTD2*LTD3))+(IPT1/(LTP1*A2))+(IPT2/(LTP2*A3
                 1))+(IDT2/(LTD2*A4))+(IDT3/(LTD3*A5)))
0421              QUBP=BP*((IPT1/(LTP1*B1))+(IPT2/(LTP2*B2))+(IDT2/(LTD2*B3))+(IDT3/
                 1(LTD3*B4)))
0422              QUCP=CP*((Z/(LTP1*LTD1*LTD2*LTD3))+(IPT1/(LTP1*C2))+(IDT1/(LTD1*C3
                 1))+(IDT2/(LTD2*C4))+(IDT3/(LTD3*C5)))
0423              QUDP=DP*((IPT1/(LTP1*D1))+(IDT1/(LTD1*D2))+(IDT2/(LTD2*D3))+(IDT3/
                 1(LTD3*D4)))
0424              QUDA3=QUBE+QUBP+QUDP
0425              QUDC3=QUAL+QUAP+QUCP
0426              DRD3=CON*(EPSDR/THMAS)*(QLDA3+QLDC3)
0427              DD3=CON*(EPSDR/THMAS)*(QUDA3+QUDC3)
                C
                C     THIS ENDS PARENT AND DAUGHTER FOR THREE COMPARTMENTS.
                C
0428           444 CONTINUE
0429               IF(J.EQ.1.OR.J.EQ.4) DRPNP=DRPNP+DRP1
0430               IF(J.EQ.2.OR.J.EQ.5) DRPTB=DRPTB+DRP1
0431               IF(J.EQ.3.OR.J.GE.6) DRPP=DRPP+DRP1
0432               IF(J.LT.8) DRPRO=DRPRO+DRP2
0433               IF(J.EQ.8) DRPL=DRP2
0434               IF(J.EQ.8) DRPRO=DRPRO+DRP3
0435               IF(J.EQ.1.OR.J.EQ.4) DRDNP=DRDNP+DRD1
0436               IF(J.EQ.2.OR.J.EQ.5) DRDTB=DRDTB+DRD1
0437               IF(J.EQ.3.OR.J.GE.6) DRDP=DRDP+DRD1
0438               IF(J.LT.8) DRDRO=DRDRO+DRD2
0439               IF(J.EQ.8) DRDL=DRD2
0440               IF(J.EQ.8) DRDRO=DRDRO+DRD3
0441               IF(J.EQ.1.OR.J.EQ.4) DPNP=DPNP+DP1
0442               IF(J.EQ.1.OR.J.EQ.4) DDNP=DDNP+DD1
0443               IF(J.EQ.2.OR.J.EQ.5) DPTB=DPTB+DP1
0444               IF(J.EQ.2.OR.J.EQ.5) DDTB=DDTB+DD1
0445               IF(J.EQ.3.OR.J.GE.6) DPP=DPP+DP1
0446               IF(J.EQ.3.OR.J.GE.6) DDP=DDP+DD1
0447               IF(J.LT.8) DPRO=DPRO+DP2
0448               IF(J.LT.8) DDRO=DDRO+DD2
0449               IF(J.GE.4.AND.J.LE.7) DPGIT=DPGIT+DP2
0450               IF(J.GE.4.AND.J.LE.7) DDGIT=DDGIT+DD2
0451               IF(J.EQ.8) DPL=DP2
0452               IF(J.EQ.8) DDL=DD2
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0453              IF(J.EQ.8) DPRO=DPRO+DP3
0454              IF(J.EQ.8) DDRO=DDRO+DD3
0455          600 CONTINUE
                  C
                  C     ALL CTB AND RET L DR AND D CALCULATED AB INITIO EACH J IFF J.EQ.8.
                  C
0456              DRTNP = DRPNP+DRDNP
0457              DRTTB=DRPTB+DRDTB
0458              DRTCTB=DRPCTB+DRDCTB
0459              DRTP=DRPP+DRDP
0460              DRTL=DRPL+DRDL
0461              DRT2R=DRP2R+DRD2R
0462              DRTRO=DRPRO+DRDRO
0463              DTNP=DPNP+DDNP
0464              DTTB=DPTB+DDTB
0465              DTCTB=DPCTB+DDCTB
0466              DTP=DPP+DDP
0467              DTL=DPL+DDL
0468              DT2R=DP2R+DD2R                                                    R
0469              DTRO=DPRO+DDRO
0470              IF(IHG.LT.0) GO TO 666
0471              DTGIT=DPGIT+DDGIT
0472              DPRAT=1.0E+2*(DPGIT/DPRO)
0473              DDRAT=1.0E+2*(DDGIT/DDRO)
0474              DTRAT=1.0E+2*(DTGIT/DTRO)
0475              IF(IFLAG.LT.0) GO TO 660
0476              WRITE(6,615)
0477          615 FORMAT(1H ,10X,34HFOR THE NASOPHYRINGIAL COMPARTMENT/)
0478              WRITE(6,655) DRPNP,DPNP,DRDNP,DDNP,DRTNP,DTNP
0479              WRITE(6,625)
0480          625 FORMAT(1H ,10X,36HFOR THE TRACHEOBRONCHIAL COMPARTMENT/)
0481              WRITE(6,655) DRPTB,DPTB,DRDTB,DDTB,DRTTB,DTTB
0482              WRITE(6,627)
0483          627 FORMAT(1H ,10X,80HFOR THE TRACHEOBRONCHIAL COMPARTMENT DUE TO CLEA    R
                 1RANCE FROM PULMONARY COMPARTMENT/)                                  R
0484              WRITE(6,655) DRPCTB,DPCTB,DRDCTB,DDCTB,DRTCTB,DTCTB                  R
0485              WRITE(6,635)
0486          635 FORMAT(1H ,10X,29HFOR THE PULMONARY COMPARTMENT/)
0487              WRITE(6,655) DRPP,DPP,DRDP,DDP,DRTP,DTP
0488              WRITE(6,645)
0489          645 FORMAT(1H ,10X,41HFOR THE LYMPH NODES, TRANSMITTED FRACTION/)         R
0490              WRITE(6,655) DRPL,DPL,DRDL,DDL,DRTL,DTL
0491              WRITE(6,647)
0492          647 FORMAT(1H ,10X,38HFOR THE LYMPH NODES, RETAINED FRACTION/)
0493              WRITE(6,655) DRP2R,DP2R,DRD2R,DD2R,DRT2R,DT2R                        R
0494          660 CONTINUE
0495              WRITE(6,665)
0496          665 FORMAT(1H ,10X,80HFOR THE REFERENCE ORGAN, PARENTHESES INDICATE PE
                 1RCENT OF TOTAL DOSE VIA GI TRACT/)
0497              WRITE(6,657) DPRAT,DDRAT,DTRAT,DRPRO,DPRO,DRDRO,DDRO,DRTRO,DTRO
0498              IF(IHG.GT.0) GO TO 700
0499          666 WRITE(6,670)
0500          670 FORMAT(1H ,10X,23HFOR THE REFERENCE ORGAN)
0501              WRITE(6,655) DRPNP,DPNP,DRDNP,DDNP,DRTNP,DTNP
0502          655 FORMAT(1H ,12X,6HPARENT,13X,6HPARENT,13X,8HDAUGHTER,12X,8HDAUGHTER
                 1,14X,5HTOTAL,14X,5HTOTAL/11X,10HDOSE  RATE,12X,4HDOSE,13X,10HDOSE
                 2 RATE,13X,4HDOSE,14X,10HDOSE  RATE,11X,4HDOSE/9X,1PE12.5,1P5E20.5/
                 3/)
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0503          657 FORMAT(1H ,12X,6HPARENT,13X,6HPARENT,13X,8HDAUGHTER,12X,8HDAUGHTER
                 1,14X,5HTOTAL,14X,5HTOTAL/11X,10HDOSE  RATE,8X,6HDOSE (,F5.2,1H),9X
                 2,10HDOSE  RATE,9X,6HDOSE (,F5.2,1H),10X,10HDOSE  RATE,9X,6HDOSE (,
                 3F5.2,1H)/9X,1PE12.5,1P5E20.5//)
0504          700 CONTINUE
0505              WRITE(6,755)
0506          755 FORMAT(1H ,60X,11HEND OF CASE)
0507              GO TO 50
0508          800 CALL EXIT
0509              STOP
0510              END
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